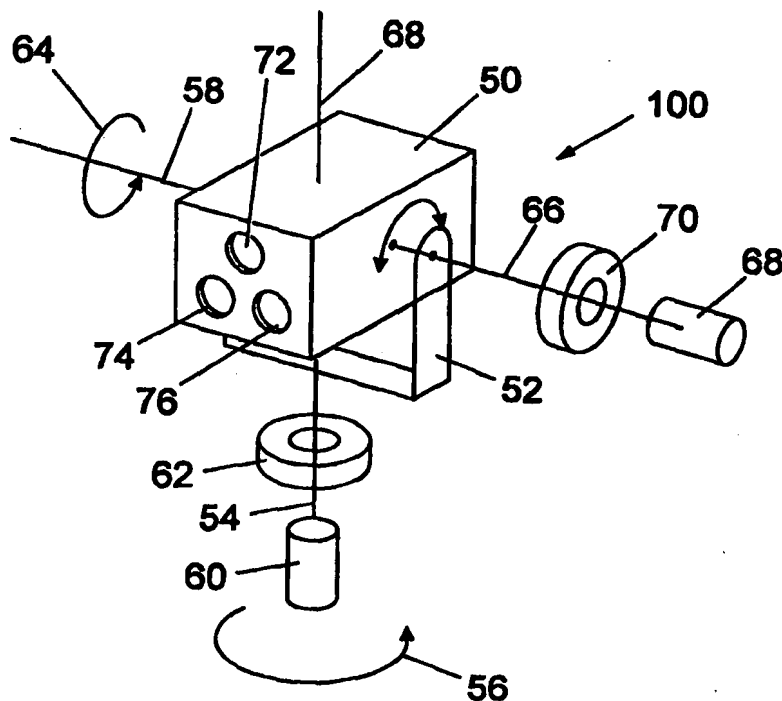




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(54) Title: SURVEY APPARATUS (57) Abstract A survey apparatus and method is provided which allows a user of the apparatus to view a target area on a screen using a camera. The image on the screen can be captured and a target within the screen selected to measure the distance or range to the target using a laser range finder.		



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1 **"Survey Apparatus"**

2

3 The present invention relates to a survey apparatus and
4 method.

5

6 Conventional survey equipment typically measures the
7 distance, bearing and inclination angle to a target
8 (such as a tree, electricity pylon or the like) or a
9 target area, with reference to the position of a user.
10 Such conventional equipment does not allow the user to
11 produce an image of the target which can be used to
12 measure heights and distances between objects within
13 the target area.

14

15 In addition, conventional sighting devices which are
16 used to select a target to be surveyed often result in
17 false surveys being made as the target is often not
18 correctly identified.

19

20 According to a first aspect of the present invention
21 there is provided a survey apparatus comprising a range
22 finder, a camera, a processor capable of processing
23 image and range signals, wherein the camera facilitates
24 aiming of the range finder.

25

1 According to a second aspect of the present invention
2 there is provided a method of measuring the range to a
3 target, the method comprising the steps of
4 providing a camera to view a target area;
5 providing a range finder;
6 using the camera to produce an image of the target
7 area;
8 selecting the target within the target area;
9 generating horizontal and vertical angles between
10 a reference point and the target; and
11 moving the range finder, if required, through the
12 generated horizontal and vertical angles to measure the
13 range to the target.

14
15 The camera is preferably a video camera, and more
16 preferably a digital video camera. The camera may
17 comprise a charge-coupled device (CCD) video camera.
18 Alternatively, the camera may comprise a digital image
19 camera. The apparatus typically includes a display
20 device to allow a user to view a target area using the
21 camera. The display device typically comprise a VGA
22 monitor. Alternatively, the display device may
23 comprise a VGA eyepiece monitor, such as a liquid-
24 crystal display (LCD) or flat panel display. This
25 offers the advantage that an image of the target may be
26 viewed by the user to ensure that the correct target
27 has been selected. Also, the survey apparatus may be
28 operated remotely using the camera to view the target
29 area.

30
31 The processor typically comprises a computer.

32
33 The range finder is typically a laser range finder.
34 Optionally, the laser range finder is bore-sighted with
35 the camera. This, in conjunction with the monitor used
36 to identify the target area, offers the advantage that

1 the user can be sure that the target area he has
2 selected will be captured by the camera, and that the
3 target area can be viewed remotely of the apparatus.
4 In addition, if the camera is bore-sighted with the
5 range finder, then any subsequent calculations made by
6 the image processor do not require an offset between
7 the camera and the range finder to be considered.

8
9 The apparatus typically calculates the range to
10 specified points and incorporates such distance
11 measurements into the image displayed on a screen.

12
13 The apparatus preferably includes a pan and tilt unit
14 for panning and tilting of the range finder and/or
15 camera. The pan and tilt unit typically comprises a
16 first motor for panning of the range finder and/or
17 camera, and a second motor for tilting of the range
18 finder and/or camera. The pan and tilt unit typically
19 includes first and second digital encoders for
20 measuring the angles of pan and tilt. The first and
21 second motors are typically controlled by the
22 processor. The outputs of the first and second
23 encoders is typically fed to the processor. This
24 provides a feedback loop wherein the motors are
25 operated to pan and tilt the range finder and/or camera
26 through the generated horizontal and vertical angles.
27 The encoders may then be used to check the angles to
28 ensure that the range finder and/or camera were panned
29 and tilted through the correct angles.

30
31 The image is preferably digitised, wherein the image
32 comprises a plurality of pixels. The reference point
33 is typically a pixel within the target area, and may be
34 a centre point of the target area or one of the
35 corners. The target is typically selected by selecting
36 a pixel within the target, using, for example, a mouse

1 pointer. This produces x and y coordinates for the
2 target pixel.

3
4 Optionally, the survey apparatus includes a compass and
5 an inclinometer and/or gyroscope. The compass is
6 typically a digital fluxgate compass. These allow the
7 bearing and angle of inclination to the target to be
8 measured. The signals from the compass, inclinometer
9 and/or gyroscope are preferably digitised to provide
10 data to the processor. The bearing and/or angle of
11 inclination to the target can be displayed on the
12 screen.

13
14 Optionally, the survey apparatus further includes a
15 position fixing system for identifying the geographical
16 position of the apparatus. The position fixing system
17 is preferably a Global Positioning System (GPS) which
18 typically includes a Differential Global Positioning
19 System (DGPS). This provides the advantage that the
20 approximate position of the apparatus can be recorded
21 (and thus the position of the target using the
22 measurements from the range finder and compass, where
23 used). The GPS/DGPS typically facilitates the time of
24 the survey to be recorded. The signal from the GPS is
25 typically digitised to provide data to the processor.

26
27 The survey apparatus is typically mounted on a mounting
28 device. The mounting device typically comprises a
29 tripod stand. The apparatus can optionally be mounted
30 on an elevating platform, telescopic elevating tube,
31 telescopic arm, robotic arm or the like. This provides
32 the apparatus with a larger viewing area. The
33 elevating platform or the like is typically capable of
34 360° rotation. This provides a complete viewing range.

35
36 The apparatus allows data gathering from within a

1 vehicle to construct a digital terrain model of the
2 terrain surrounding the vehicle.
3
4 The method typically comprises any one, some or all of
5 the further steps of
6 obtaining a focal length of the camera;
7 obtaining a field of view of the camera;
8 calculating the principal distance of the camera;
9 obtaining the horizontal offset and vertical
10 offset between an axis of the camera and an axis of the
11 laser;
12 calculating the horizontal and vertical offsets in
13 terms of pixels;
14 calculating the difference between the horizontal
15 and vertical offsets in terms of pixel and the x and y
16 coordinates of the target pixel; and
17 calculating the horizontal and vertical angles.
18
19 Optionally, the method typically includes one, some or
20 all of the further steps of
21 instructing the pan and tilt unit to pan and tilt
22 the range finder and/or camera through the vertical and
23 horizontal angles;
24 measuring the horizontal and vertical angles using
25 the encoders;
26 verifying that the angles through which the range
27 finder and/or camera are moved is correct;
28 obtaining horizontal and/or vertical correction
29 angles by subtracting the measured horizontal and
30 vertical angles from the calculated horizontal and
31 vertical angles;
32 adjusting the pan and tilt of the range finder
33 and/or camera if necessary; and
34 firing the range finder to obtain the range to the
35 target.
36

1 Embodiments of the present invention shall now be
2 described, with reference to the accompanying drawings,
3 in which:-

4 Fig. 1 is a schematic representation of a image
5 capture and laser transmitter and receiver unit in
6 accordance with, and for use with, the present
7 invention;

8 Fig. 2 shows schematically a first embodiment of
9 survey apparatus;

10 Fig. 3 shows an exploded view of the survey
11 apparatus of Fig. 2 in more detail;

12 Fig. 4 shows a simplified schematic illustration
13 of a digital encoder;

14 Fig. 5 schematically shows the survey apparatus of
15 Figs 2 and 3 in use;

16 Fig. 6 is a schematic representation of the
17 display produced on a computer screen of a freeze
18 frame image produced by a digital camera;

19 Fig. 7 is a simplified schematic diagram of inside
20 a digital camera;

21 Fig. 8 is a simplified diagram illustrating how a
22 principal distance (PD) may be calculated;

23 Fig. 9 is a simplified diagram illustrating the
24 offset between the laser and the camera in use;

25 Fig. 10 is a schematic representation illustrating
26 a horizontal offset H_{offset} outwith the camera;

27 Fig. 11 is a schematic representation illustrating
28 a horizontal distance l_x in terms of pixels,
29 corresponding to H_{offset} , within the camera;

30 Fig. 12 is a simplified diagram of a freeze frame
31 image showing an object;

32 Fig. 13 is a schematic representation illustrating
33 the relationship between a horizontal distance d_x ,
34 a principal distance PD and an angle θ ;

35 Fig. 14 is a schematic representation of a screen
36 image of a target overlaid with range, bearing

1 and inclination information;
2 Fig. 15a is a schematic representation of a
3 vehicle provided with an elevating arm and survey
4 apparatus showing the position of the apparatus
5 when the vehicle is moving;
6 Fig. 15b is a schematic representation of the
7 vehicle of Fig. 15a with the apparatus deployed on
8 the arm;
9 Fig. 15c is a schematic representation of the
10 vehicle of Figs 15a and 15b on a slope with the
11 apparatus deployed on the arm;
12 Figs 16a and 16b are respective rear and side
13 views of the survey apparatus deployed on the arm;
14 Fig. 17 is an exemplary screen shot of an area
15 which has been surveyed using the survey
16 apparatus;
17 Figs 18a and 18b are respective side and plan
18 elevations of the vehicle of Figs 15a to 15c
19 illustrating the survey apparatus being used to
20 profile the ground in front of the vehicle;
21 Figs 19a and 19b are side and plan views of the
22 profile of the ground in front of the vehicle
23 which is displayed for a user of the apparatus;
24 Fig. 20 illustrates a head-up display used by the
25 driver of the vehicle, the display being generated
26 by the survey apparatus;
27 Fig. 21 illustrates calculating the height
28 difference between two points A and B using the
29 survey apparatus;
30 Fig. 22 illustrates calculating the height and
31 distance between two points A and B using the
32 survey apparatus; and
33 Fig. 23 illustrates using the survey apparatus to
34 profile a surface.
35
36 Referring to the drawings, Fig. 1 shows a schematic

1 representation of an image capture and laser
2 transmitter and receiver unit 10 for use with the
3 present invention. Unit 10 includes a laser 12 (which
4 forms part of a laser range finder) which generates a
5 beam of laser light 14. The laser 12 is typically an
6 invisible, eyesafe, gallium arsenide (GaAs) diode laser
7 which emits a beam typically in the infra-red (IR)
8 spectrum. The laser 12 is typically externally
9 triggered and is designed to measure up to 1000 metres
10 or more to reflective and non-reflective targets. Any
11 particular type of laser 12 may be used and the present
12 invention is not limited to the particular embodiment
13 shown.

14

15 The beam 14 is reflected by a part-silvered prism 16 in
16 a first direction substantially perpendicular to the
17 direction of the initial beam 14, thereby creating a
18 transmit beam 18. The transmit beam 18 enters a series
19 of transmitter optics 20 which collimates the transmit
20 beam 18 into a target beam 22. The target beam 22 is
21 reflected by a target (schematically shown in Fig. 1 at
22 24) and is returned as a reflected beam 26. The
23 reflected beam 26 is collected by a series of receiver
24 optics 28 and directs it to a laser light detector 30.
25 The axes of the transmit and receiver optics 20, 28 are
26 calibrated to be coincident at infinity.

27

28 Signals from the detector 30 are sent to a processor
29 (not shown) which calculates the distance from the
30 apparatus 10 to the target 24 using a time-of-flight
31 principle. Thus, by dividing the time taken for the
32 light to reach the target 24 and be reflected back to
33 the detector 30 by two, the distance to the target 24
34 may be calculated.

35

36 Bore-sighted with the laser 12 (using the part-silvered

1 prism 16) is a digital video camera 32. The camera 32
2 is preferably a complementary metal-oxide silicon
3 (CMOS) camera which is formed on a silicon chip. The
4 chip generally includes all the necessary drive
5 circuitry for the camera 32. It should be noted that
6 the camera need not be bore-sighted with the laser. In
7 this case, the transmit laser beam 22 will be offset in
8 the x and/or y directions from the centre of the
9 picture taken by the camera 32. The offsets can be
10 calculated and the survey apparatus calibrated (using
11 software) to take into account the offsets, as will be
12 described.

13
14 The transmit optics 20 serve a dual purpose by also
15 acting as a lens for the camera 32. Thus, light which
16 enters the transmit optics 20 is collimated and
17 directed to the camera 32 (shown schematically at 34)
18 thereby producing an image of the target 24 at the
19 camera 32. The image which the camera 32 receives is
20 digitised and sent to a processor (not shown). It
21 should be noted that a separate lens may be used for
22 the camera 32 if required.

23
24 Referring now to Figs 2 and 3, Fig. 2 shows
25 schematically a first embodiment of survey apparatus
26 100 mounted for movement in x and y directions, and
27 Fig. 3 shows an exploded view of the survey apparatus
28 100 of Fig. 2 in more detail.

29
30 Referring firstly to Fig. 2, the image capture and
31 laser transmitter and receiver unit 10 (Fig. 1) is
32 typically mounted within a casing 50. The casing 50 is
33 typically mounted to a U-shaped yoke 52, yoke 52 being
34 coupled to a vertical shaft 54. Shaft 54 is rotatably
35 mounted to facilitate rotational movement (indicated by
36 arrow 56 in Fig. 2) of the casing 50 in a horizontal

1 plane (indicated by axis 58) which is the x-direction.
2 The rotational movement of the shaft 54 (and thus the
3 yoke 52 and casing 50) is controlled by a motor 60
4 coupled to the shaft 54, typically via a gearbox (not
5 shown in Fig. 2). The operation of the motor 60 is
6 controlled by the computer.

7
8 The angle of rotation of the casing 50 in the
9 horizontal plane (ie the x-direction) is measured
10 accurately by a first digital encoder 62, attached to
11 the shaft 54 in a known manner, which measures the
12 angular displacement of the casing 50 (and thus the
13 transmit laser beam 22) in the x-direction.

14
15 Similarly, the yoke 52 allows the casing 50 (and thus
16 the transmit laser beam 22) to be displaced in the y-
17 direction as indicated by arrow 64. The casing 50 is
18 mounted to the yoke 52 via a horizontal shaft 66.
19 Shaft 66 is rotatably mounted to facilitate rotational
20 movement (indicated by arrow 64 in Fig. 2) of the
21 casing 50 in a vertical plane (indicated by axis 68)
22 which is the y-direction. The rotational movement of
23 the shaft 66 (and thus the yoke 52 and casing 50) is
24 controlled by a motor 68 coupled to the shaft 56,
25 typically via a gearbox (not shown in Fig. 2). The
26 operation of the motor 66 is controlled by the
27 computer.

28
29 The angle of rotation of the casing 50 in the vertical
30 plane (ie the y-direction) is measured accurately by a
31 second digital encoder 70, attached to shaft 66 in a
32 known manner, which measures the angular displacement
33 of the casing 50 (and thus the transmit laser beam 22)
34 in the y-direction. Thus, the motors 60, 68 provide
35 for panning and tilting of the casing 50.

36

1 The output of the first and second encoders 62, 70 is
2 electrically coupled to the computer to provide a
3 feedback loop. The feedback loop is required because
4 the motors 60, 68 are typically coupled to the shafts
5 54, 66 via respective gearboxes and are thus not in
6 direct contact with the shafts 54, 66. This makes the
7 movement of the casing 50 which is effected by
8 operation of the motors 60, 68 less accurate. However,
9 as the encoders 62, 70 are coupled directly to their
10 respective shafts 54, 66 then the panning and tilting
11 of the casing in the x- and y-directions can be
12 measured more accurately, as will be described.

13
14 The embodiment of the image capture and laser
15 transmitter and receiver unit 10 shown in Fig. 2 is
16 slightly different from that illustrated in Fig. 1.
17 The camera within unit 10 is not bore-sighted with the
18 laser, and thus casing 50 is provided with a camera
19 lens 72, a laser transmitter lens 74 and a laser
20 receiver lens 76. It should be noted that the laser
21 transmitter lens 74 and the camera lens 72 may be
22 integrated into a single lens as illustrated in Fig. 1.
23 Ideally, the camera lens 72, laser transmitter lens 74
24 and laser receiver lens 76 would be co-axial. This
25 could be achieved in practice by mechanically adjusting
26 the lenses 72, 74, 76 to make them co-axial. However,
27 this is a time consuming process and the offsets
28 between the lenses can be calculated and the survey
29 apparatus can be calibrated to take these offsets into
30 account, as will be described. This calibration is
31 generally simpler and quicker than mechanically
32 aligning the lenses 72, 74, 76.

33
34 Referring to Fig. 3, there is shown in more detail the
35 apparatus of Fig. 2. It should be noted that the
36 casing 50 which houses the image capture and laser

1 transmitter and receiver unit 10 is not provided with a
2 separate camera lens (as in Fig. 2). It should also be
3 noted that the casing 50 in Fig. 3 is mounted to
4 facilitate rotational movement in the x-direction, but
5 can be manually tilted in the y-direction.

6
7 As can be seen more clearly in Fig. 3, the casing 50 is
8 mounted to the U-shaped yoke 52. The yoke 52 is
9 coupled to the shaft 54 using any conventional means
10 such as screws 80. The shaft 54 is driven by the
11 stepper motor 60 via a worm/wheel drive gearbox 82.
12 The digital encoder 62 is provided underneath a plate
13 84 through which the shaft 54 passes and to which the
14 gearbox/motor assembly is attached. Plate 84 also
15 includes a rotary gear assembly 86 which is driven by
16 the motor 60 via the worm gearbox 82 to facilitate
17 rotational movement of the shaft 54.

18
19 The motor, gearbox and shaft assembly is mounted within
20 an aluminium casing 86, the casing 86 also having a
21 rack 88 mounted therein. The rack 88 contains the
22 necessary electronic circuitry for driving and
23 controlling the operation of the survey apparatus, and
24 includes a stepper motor driver board 90, a laser
25 control board 92 and an interface board 94.

26
27 The first and second digital encoders 62, 70 may be of
28 any conventional type, such as Moir Fringe, barcode or
29 mask. Moir fringe type encoders are typically used as
30 they are more accurate. Fig. 4 shows a simplified
31 schematic illustration of a digital encoder, generally
32 designated 110. Encoder 110 typically comprises a
33 casing 112 in which a disc 114 is rotatably mounted.
34 The disc 114 is provided with a pattern and is
35 typically at least partially translucent. The type of
36 pattern defined on the disc 114 determines the type of

1 encoder.

2

3 A light emitting diode (LED) 116 is suspended above the
4 disc 114 and emits a light beam (typically collimated
5 by a lens (not shown) which shines through the disc
6 114. The light emitted by the LED 116 is detected by a
7 detector, typically a cell array 118. As the disc 114
8 rotates (in conjunction with the shaft to which it is
9 coupled) a number of electrical outputs are generated
10 per revolution of the disc 114 by the cell array 118
11 which detects the light passing through the disc 114
12 from the LED 116. These types of encoders usually have
13 two output channels (only one shown in Fig. 4) and the
14 phase relationship between the two signals can be used
15 to determine the direction of rotation of the disc 114.

16

17 The encoder 110 produces a pulse output per unit of
18 revolution. Thus, as the disc 114 rotates, the pattern
19 on the disc 114 causes electrical pulses to be
20 generated by the cell array 118 in response to the
21 pattern on the disc 114. These pulses can be counted
22 and, given that one pulse is proportional to a certain
23 degree of rotation, the angular rotation of the disc
24 114 and thus the shaft 54 can be calculated.

25

26 Fig. 5 shows the survey apparatus 100 (schematically
27 represented in Fig. 5 but shown more clearly in Figs 2
28 and 3) in use. The apparatus 100 is controlled and
29 operated using software installed on the computer
30 (shown schematically at 120) via a cable 122, telemetry
31 system or other remote or hardwired control. An image
32 of the target is displayed on the computer screen using
33 the camera 32 (Fig. 1) and is schematically shown as
34 image 124 in Fig. 5. When the image 124 of the target
35 area of interest is viewed on the screen, the user of
36 the apparatus 100 instructs the camera 32 (included as

1 part of the apparatus 100) to take a freeze frame image
2 of the target area. The freeze frame image 124 is a
3 digital image made up of a plurality of pixels and Fig.
4 6 is a schematic representation of the display produced
5 on the computer screen of the freeze frame image 124.
6 The image 124 is typically divided into an array of
7 pixels, with the image containing, for example, 200 by
8 200 pixels in the array.

9
10 Each pixel within the array has an x and y coordinate
11 associated with it using, for example, the centre C of
12 the picture as a reference point. Thus, each pixel
13 within the digital image can be individually addressed
14 using these x and y co-ordinates.

15
16 The individual addresses for each pixel allow the user
17 to select a particular object (for example a tree 126)
18 within the digital image 124. The tree 126 can be
19 selected using a mouse pointer for example, where the
20 mouse pointer is moved around the pixels of the digital
21 image by movement of a conventional mouse provided with
22 the computer in a known manner. The x and y
23 coordinates of each pixel may be displayed on the
24 screen as the mouse pointer is moved around the image.
25 Clicking the mouse button with the pointer on the tree
26 126 selects a particular pixel 128 within the array
27 which is identified by its x and y coordinates.

28
29 The computer is then used to calculate the horizontal
30 angle H_A and the vertical angle V_A (Fig. 6). The
31 horizontal angle H_A and the vertical angle V_A are the
32 relative angles between the centre point C of the image
33 and the pixel 128, as schematically shown in Fig. 6.

34
35 The methodology for calculating the horizontal angle H_A
36 and the vertical angle V_A from the pixel x, y

1 coordinates is as follows. Fig. 7 is a simplified
2 schematic diagram of inside the camera 32 which shows
3 the camera lens 72 and a charge-coupled device (CCD)
4 array 130. The camera 32 is typically a zoom camera
5 which therefore has a number of focal lengths which
6 vary as the lens 72 is moved towards and away from the
7 CCD array 130.

8
9 Referring to Fig. 7, the angles of horizontal and
10 vertical views, or the field of view in the horizontal
11 and vertical direction θ_H , θ_V (θ_V not shown in Fig. 7)
12 can be calibrated and calculated at different focal
13 lengths of the camera 32. For simplicity, it is
14 assumed that the CCD array 130 is square, and thus the
15 field of view in the horizontal and vertical directions
16 θ_H , θ_V will be the same, and thus only the field of view
17 in the horizontal direction θ_H will be considered. The
18 methodology described below considers one zoom position
19 only.

20
21 Having calculated (or otherwise obtained) the field of
22 view in the horizontal direction θ_H then the principal
23 distance PD (in pixels) can be calculated. The
24 principal distance PD is defined as the distance from
25 the plane of the lens 72 to the image plane (ie the
26 plane of the CCD array 130).

27
28 Referring to Fig. 8, if the image width on the CCD
29 array is defined as H_R , then using basic trigonometry
30 $\tan(\theta_H/2) = H_R/(2PD)$. Thus,

31

$$32 \quad PD = H_R/2(\tan(\theta_H/2))$$

33

34 If the distance between each pixel in the image 124 in
35 a certain unit (ie millimetres) is known, then the
36 principal distance PD can be converted into a distance

1 in pixels. For example, if the field of view in the
 2 horizontal and vertical angles θ_H , θ_V is, for example
 3 10° , and the image contains 200 by 200 pixels, then
 4 moving one twentieth of a degree in the x or y
 5 direction is the equivalent of moving one pixel in the
 6 x or y direction.

7
 8 When initially using the apparatus 100, the camera 32
 9 is used to take a calibration freeze frame image and
 10 the laser 12 is activated to return the range R to the
 11 centre point C of the image. However, the laser axis
 12 is typically offset from the camera axis. The
 13 horizontal and vertical offsets between the laser axis
 14 and the camera axis when the freeze frame image is
 15 taken are defined as H_{offset} and V_{offset} and are known.
 16 Knowing the range R and the horizontal and vertical
 17 offsets H_{offset} , V_{offset} allows the offset horizontal and
 18 vertical distances l_x and l_y in terms of pixels to be
 19 calculated. Referring to Fig. 9, the centre point C of
 20 the image 124 taken by the camera 32 and the laser spot
 21 132 where the transmit laser beam 22 hits the target
 22 area is typically offset by the horizontal and vertical
 23 distances l_x and l_y .

24
 25 Fig. 10 is a schematic representation illustrating the
 26 horizontal offset H_{offset} outwith the camera 32, and Fig.
 27 11 is a schematic representation illustrating the
 28 horizontal distance l_x in terms of pixels, corresponding
 29 to H_{offset} , within the camera 32. Referring to Figs 10
 30 and 11 and using basic trigonometry,

$$\tan \theta = H_{offset}/R$$

33 and,

$$l_x = PD(\tan \theta)$$

35 Thus,

$$l_x = PD(H_{offset}/R)$$

1 and it follows that

$$2 \quad l_y = PD(V_{offset}/R)$$

3

4

5

6 If the range to a certain object within the target area
7 (such as the tree 126 in Fig. 6) is required, then the
8 computer must calculate the horizontal and vertical
9 angles H_A , H_V through which the casing 50 and thus the
10 laser beam 22 must be moved in order to target the
11 object.

12

13 The user selects the particular pixel (relating to the
14 object of interest) within the image using a mouse
15 pointer. In Fig. 12, the selected object is
16 represented by pixel A which has coordinates (x, y) ,
17 and the laser spot 132 has coordinates (l_x, l_y)
18 calculated using the previous method. The coordinates
19 (x, y) of point A are already known using the
20 coordinates of the pixel array of the image.

21

22 If the horizontal distance between pixel A and the
23 laser spot 132 is defined as d_x , and similarly the
24 vertical distance between pixel A and the laser spot
25 132 is defined as d_y , then

26

$$27 \quad d_x = x - l_x$$

28 and

$$29 \quad d_y = y - l_y,$$

30

31 and it follows that the horizontal and vertical angles
32 H_A , V_A can be calculated as

33

$$34 \quad H_A = \text{inverse tan } (d_x/PD)$$

35

36 and

1 $V_A = \text{inverse tan } (d_y/PD).$

2

3 Referring back to Fig. 2, having calculated the
4 horizontal and vertical angles H_A , V_A through which the
5 casing 50 must be rotated to measure the range to the
6 object A, the computer 120 instructs the motor 60 to
7 pan through an angle of H_A and simultaneously instructs
8 the motor 68 to tilt through an angle of V_A . Thus, the
9 transmit laser beam 22 is directed at the object A
10 selected by the user to determine the range to it.

11

12 However, the motors 60, 68 are not directly coupled to
13 the shafts 54, 66 (but via respective gearboxes) and
14 thus can have errors which results in the laser beam 22
15 not being directed precisely at the object A. However,
16 the encoders 62, 70 can be used to measure more
17 precisely the angles H_A and V_A through which the casing
18 50 was panned and tilted. If there is a difference
19 between the measured angles H_A and V_A and the angles
20 which were calculated as above, the computer can
21 correct for this and can pan the casing 50 through an
22 angle H_{AC} which is the difference between the calculated
23 angle H_A and the measured angle H_A , and similarly tilt
24 the casing 50 through an angle V_{AC} which is the
25 difference between the calculated angle V_A and the
26 measured angle V_A . The process can then be repeated by
27 using the encoders 62, 70 to check that the casing 50
28 has been panned and tilted through the angles H_{AC} and
29 V_{AC} . If there is a difference again, then the process
30 can be repeated to further correct for the errors
31 introduced. This iteration process can be continued
32 until the output from the decoders 62, 70 corresponds
33 to the correct angles H_A and V_A . The laser 12 is then
34 fired to give the range to the object A.

35

36 The user may then select another object within the

1 image 124 which is of interest and use the above
2 process to determine the range to that particular
3 object. It should be noted however, that the process
4 to determine the distances l_x and l_y need not be
5 repeated as these distances will be constants.

6
7 The apparatus 100 can optionally include a Global
8 Positioning System (GPS) (not shown). The GPS is a
9 satellite navigation system which provides a three-
10 dimensional position of the GPS receiver (in this case
11 mounted as part of the survey apparatus 100) and thus
12 the position of the survey apparatus 100. The GPS is
13 used to calculate the position of the apparatus 100
14 anywhere in the world to within approximately ± 25
15 metres. The GPS calculates the position of the
16 apparatus 100 locally using radio/satellite broadcasts
17 which send differential correction signals to ± 1
18 metre. The GPS can also be used to record the time of
19 all measured data to 1 microsecond.

20
21 The apparatus 100 may further include an inclinometer
22 (not shown) and a fluxgate compass (not shown), both of
23 which would be mounted within the casing 50. The
24 fluxgate compass generates a signal which gives a
25 bearing to the target and the inclinometer generates a
26 signal which gives the incline angle to the target.
27 These signals are preferably digitised so that they are
28 in a machine-readable form for direct manipulation by
29 the computer 120.

30
31 Thus, in addition to being used to find ranges to
32 specific targets, the survey apparatus may also be used
33 to determine the position of objects, such as
34 electricity pylons, buildings, trees or other man-made
35 or natural structures. The GPS system can be used to
36 determine the position of the apparatus 100 anywhere in

1 the world, which can be recorded. Optionally, the
2 fluxgate compass within the casing 50 measures the
3 bearing to the target, which can be used to determine
4 the position of the target using the reading from the
5 GPS system and the reading from the fluxgate compass.
6

7 It should also be noted that the encoders 62, 70 may be
8 used to determine the bearing to the target instead of
9 the fluxgate compass. In this case, if the encoder is
10 given an absolute reference, such as the bearing to an
11 electricity tower or other prominent landmark which is
12 either known or can be calculated, then the angle
13 relative to the reference bearing can be calculated
14 using the outputs from the encoders 62, 70, thus giving
15 the bearing to the target.
16

17 In addition, the position of the apparatus and the
18 calculated position of the target could be overlaid on
19 a map displayed on the computer screen so that the
20 accuracy of the map can be checked. This would also
21 allow more accurate maps to be drawn.
22

23 Referring to Fig. 14, there is shown an exemplary image
24 printed from the screen of the computer 120. The
25 survey apparatus 100 of the present invention is
26 advantageously operated remotely. As the apparatus 100
27 is computer-controlled, remote operation of the system
28 can be achieved via the Internet, a telemetry link or a
29 phone line for example. The survey apparatus 100 is
30 particularly suited to applications where surveying is
31 required in hazardous and/or hostile environments.
32

33 Thus, as show in Fig. 14, the screen image may include
34 a sighting graticule 150 which allows the user to
35 select the target with increased accuracy. The
36 orientation of the apparatus 100 can be moved using any

1 particular control means associated with the computer
2 such as a mouse, joystick or the like. In particular,
3 the apparatus 100 may be moved by the user clicking on
4 a particular target within the image on the screen
5 using a mouse for example. As the apparatus is moved,
6 the camera 32 will display an image on the screen which
7 the user can use to determine the target area.

8
9 Thereafter, the apparatus 100 will be activated by
10 pressing a key, clicking a mouse button or by any other
11 conventional means, and the camera 32 will take the
12 freeze frame which will be displayed on the computer
13 screen. The user can then select which target he
14 wishes to range too within the picture using the mouse
15 pointer. This will give the two-dimensional x, y pixel
16 coordinates for the selected object. The computer 120
17 may then calculate the horizontal and vertical angles
18 H_A , V_A as described above. The computer 120 then
19 instructs the motors 60, 68 to pan and tilt through
20 their respective angles until the laser transmit beam
21 22 is pointing at the object of interest. This may
22 require the iteration process described above to ensure
23 that the laser beam 22 is accurately aligned with the
24 target object. Once the beam 22 is aligned with the
25 object, the laser 12 will be activated to determine the
26 range R to a particular object. Once the range is
27 known, the screen image can be overlaid with the range
28 and the horizontal and vertical angles H_A , V_A , as
29 indicated generally by 152 in Fig. 14. This
30 information can then be saved for future reference
31 and/or analysis.

32
33 The apparatus 100 is particularly suited to
34 applications in hostile and/or hazardous environments.
35 The apparatus 100 can be operated remotely and thus
36 ensures that the user can survey an area of interest

1 from a relatively safe, remote environment.

2

3 The apparatus 100 can be mounted on top of a tripod
4 stand, mounted on a vehicle on a telescopic mast, or on
5 an elevated platform for greater visibility. The
6 apparatus 100 can be used to measure the range to most
7 types of surfaces including earth, coal, rock and
8 vegetation at distance in excess of 1 kilometre (km).

9

10 Referring to Figs 15a to c, there is shown a vehicle
11 160 (such as a tank) which is provided with the
12 apparatus 100 mounted on a telescopic or extendable arm
13 162. As illustrated in Fig. 15a, the apparatus 100 may
14 be completely retracted when the vehicle 160 is in
15 motion, and may be stored behind an armoured shield
16 164. The casing 50 of the apparatus 100 would tilt
17 downwards to a horizontal attitude and the telescopic
18 arm 162 would extend so that the apparatus 100 was
19 substantially protected by the armoured shield 164.

20

21 When the area to be surveyed is reached, the vehicle is
22 stopped and the apparatus 100 deployed on the
23 telescopic arm 162 by reversing the procedure described
24 above, as illustrated in Fig. 15b. The telescopic arm
25 is preferably mounted on a rotation joint 166 so that
26 the apparatus 100 can be rotated through 360° as
27 indicated by arrow 168 in the enlarged portion of Fig.
28 15b. A motor 170 is coupled to the rotation joint 166
29 to facilitate rotation of the joint 166. The apparatus
30 100 can typically be raised to a height of
31 approximately 15 metres or more, depending upon the
32 construction of the arm 162.

33

34 The particular configuration shown in Figs 15a and 15b
35 can accommodate large angles of roll and pitch of the
36 vehicle, such as that shown in Fig. 15c. In Fig. 15c,

1 the vehicle 160 is stationary on a slope 172 and has
2 been rolled through an angle indicated by arrow 174 in
3 Fig. 15c. The user or the computer can correct for the
4 angle of roll 174 by moving the arm 162 until the
5 inclinometer indicates that the apparatus 100 is level.
6 A level 178 (Figs 16a, 16b) may be provided on the base
7 of the apparatus 100 if required.

8
9 Figs 16a and 16b are front and side elevations of the
10 apparatus 100 mounted on the arm 162. As can be seen
11 from Figs 16a and 16b, the arm 162 can be rotated
12 through 360° as indicated by arrow 176 in Fig. 16a.
13 The apparatus 100 is mounted on a pan and tilt head 180
14 to facilitate panning and tilting of the apparatus 100.

15
16 Servo motors within the pan and tilt head 180 pan and
17 tilt the head 180 into the plane of roll and pitch of
18 the vehicle 160 (Fig. 15c). Thereafter, the motors 60,
19 68 of the apparatus 100 pan and tilt the apparatus 100
20 until it is level, using the level indicator 178 as a
21 guide.

22
23 Further electronic levels (not shown) within the
24 apparatus 100 can measure any residual dislevelment
25 and this can be corrected for in the software before
26 any measurements are taken.

27
28 A particular application of the apparatus 100 deployed
29 on a vehicle 160 would be in a military operation. The
30 apparatus 100 can be deployed remotely on the arm 162
31 and used to survey the area surrounding the vehicle
32 160. The computer 120 could be provided with a ground
33 modelling software package wherein the user selects a
34 number of key targets within the area using the method
35 described above, and finds the range and bearing to,
36 height of and global position of (if required) these

1 targets. The software package will then plot these
2 points, including any heights which the GPS 182 (Figs
3 16a, 16b) can generate, and in-fill or morph the
4 remaining background to produce an image of the
5 terrain, such as that shown in Fig. 17.

6
7 Fig. 17 shows an exemplary terrain which has been
8 surveyed, the terrain including a river 190, the river
9 190 being in a valley with sides 192, 194 raising
10 upwardly from the river 190. Once the ground has been
11 modelled, design templates of equipment carried by the
12 vehicle 160 (or any other vehicle, aircraft etc) can be
13 overlaid over the image to assess which type of
14 equipment is required to cross the obstacle, such as
15 the river 190. The surveying operation can be done
16 discretely and in a very short time compared with
17 conventional survey techniques. Such conventional
18 techniques would typically be to deploy a number of
19 soldiers to survey the area manually and report back.
20 However, with the apparatus 100 deployed on the vehicle
21 160 the survey can be done quicker, more accurately and
22 more safely, without substantial risk to human life.

23
24 It is possible to conduct multiple surveys with the
25 vehicle 160 in one or more locations, with the data
26 from each survey being integrated to give a more
27 accurate overall survey of the surrounding area.

28
29 Furthermore, if the arm 162 was disposed at the front
30 of the vehicle 160 as shown in Figs 18a and 18b, the
31 apparatus 100 can be used to check the profile of the
32 ground in front of the vehicle 160. Thus, the profile
33 of the ground could be shown in profile and plan views
34 as illustrated in Figs 19a, and 19b respectively.
35 Alternatively, or additionally, the software on the
36 computer 120 could be used to generate a head-up video

1 display to which the driver of the vehicle 160 could
2 refer. Fig. 20 illustrates an example of the type of
3 head-up display which could be generated. The heading
4 of the tank (measured by the fluxgate compass) is
5 displayed, with the range to and height of the ground
6 (and any obstructions) in front of the vehicle also
7 being displayed. The height displayed could be the
8 height relative to the vehicles' position, or could be
9 the absolute height obtained from the GPS 182.

10

11 Figs 21 to 23 illustrate three further applications of
12 the apparatus 100. Fig. 21 illustrates how to
13 calculate the height between two points A and B
14 (indicated by crosses in Fig. 21). The user will
15 select the points A and B and then measure the range to
16 them using the method described above. This will give
17 three-dimensional coordinates for each point A and B.
18 If it is assumed that the range to each point is
19 approximately equal (which can be checked using the
20 measured ranges) and that the x co-ordinates for each
21 point are approximately equal (this can be done using
22 the display of x, y and z co-ordinates displayed on the
23 screen), then the height from A to B is given by
24 subtracting their respective y coordinates. This can
25 then be displayed within a separate window within the
26 screen, for example.

27

28 Fig. 22 illustrates the technique used to measure the
29 height and distance between two points A and B. The
30 range to A and B are first measured using the apparatus
31 100 as described above. The slope from A to B, the
32 horizontal difference between A and B and the gradient
33 of A to B are then calculated, the results being
34 overlaid on the screen.

35

36 Fig. 23 illustrates how a rock face or the like may be

1 profiled. Range measurements are taken at intervals
2 along the profile (indicated by crosses in Fig. 23).
3 The height of each measurement will be calculated from
4 either the inclinometer reading or can be determined
5 using the GPS 182. Thus, a rock profile may be
6 produced, as shown in Fig. 23.

7
8 While the above is a description of the typical
9 applications which the survey apparatus of the present
10 invention may be used for, it will be apparent to those
11 skilled in the art the full range of applications of
12 the survey apparatus disclosed herein, and the present
13 invention is not limited to the examples discussed.

14
15 Thus, there is provided a survey apparatus and method
16 which provides for remote control operation using a
17 video camera to relay images back to a host computer in
18 real-time. The image on the host computer allows the
19 user to select particular objects of interest within
20 the surveyed area and measure the range to these
21 objects. The apparatus can also be used to determine
22 rock profiles, heights between two points, the position
23 of certain objects and the like.

24
25 Modifications and improvements may be made to the
26 foregoing without departing from the scope of the
27 present invention.

28

1 **CLAIMS**

2

3 1. A survey apparatus comprising a range finder, a
4 camera and a processor capable of processing image and
5 range signals, wherein the camera facilitates aiming of
6 the range finder.

7

8 2. A survey apparatus according to claim 1, wherein
9 the camera comprises a video camera.

10

11 3. A survey apparatus according to either preceding
12 claim, wherein the camera comprises a digital camera.

13

14 4. A survey apparatus according to any preceding
15 claim, wherein the apparatus includes a display device
16 to allow a user of the apparatus to view a target area
17 using the camera.

18

19 5. A survey apparatus according to claim 4, wherein
20 the display device comprises a VGA monitor.

21

22 6. A survey apparatus according to any preceding
23 claim, wherein the processor comprises a computer.

24

25 7. A survey apparatus according to any preceding
26 claim, wherein the range finder comprises a laser range
27 finder.

28

29 8. A survey apparatus according to any preceding
30 claim, wherein the range finder is bore-sighted with
31 the camera.

32

33 9. A survey apparatus according to any preceding
34 claim, wherein the apparatus includes a pan and tilt
35 unit for panning and tilting of the range finder and/or
36 camera.

1 10. A survey apparatus according to claim 9, wherein
2 the pan and tilt unit comprises a first motor for
3 panning of the range finder and/or camera, and a second
4 motor for tilting of the range finder and/or camera.

5

6 11. A survey apparatus according to either claim 9 or
7 claim 10, wherein operation of the first and second
8 motors is controlled by the processor.

9

10 12. A survey apparatus according to any one of claims
11 9 to 11, wherein the pan and tilt unit includes first
12 and second digital encoders for measuring the angles of
13 pan and tilt.

14

15 13. A survey apparatus according to claim 12, wherein
16 the outputs of the first and second encoders are fed to
17 the processor.

18

19 14. A survey apparatus according to claim 13, wherein
20 a feedback loop is provided wherein the motors are
21 capable of being operated to pan and tilt the range
22 finder and/or camera through the generated horizontal
23 and vertical angles, and the encoders are capable of
24 verifying the angles moved to verify that the range
25 finder and/or camera were panned and tilted through the
26 correct angles.

27

28 15. A survey apparatus according to any one of claims
29 12 to 14, wherein the first and second encoders are
30 used to calculate the bearing to the target.

31

32 16. A survey apparatus according to according to any
33 preceding claim, wherein the image is digitised.

34

35 17. A survey apparatus according to claim 16, wherein
36 the image comprises a plurality of pixels.

1 18. A survey apparatus according to claim 17, wherein
2 the reference point comprises a pixel within the target
3 area.
4

5 19. A survey apparatus according to any preceding
6 claim, wherein the reference point comprises a centre
7 point of the target area.
8

9 20. A survey apparatus according to any one of claims
10 16 to 19, wherein the target is selected by selecting a
11 pixel within the target.
12

13 21. A survey apparatus according to any preceding
14 claim, wherein the survey apparatus includes a compass
15 and an inclinometer and/or gyroscope.
16

17 22. A survey apparatus according to claim 21, wherein
18 the compass comprises a digital fluxgate compass.
19

20 23. A survey apparatus according to either claim 21 or
21 claim 22, wherein signals from the compass,
22 inclinometer and/or gyroscope are processed to provide
23 data to the processor.
24

25 24. A survey apparatus according to any preceding
26 claim, wherein the survey apparatus further includes a
27 position fixing system for identifying the geographical
28 position of the apparatus.
29

30 25. A survey apparatus according to claim 24, wherein
31 the position fixing system comprises a Global
32 Positioning System.
33

34 26. A survey apparatus according to claim 25, wherein
35 the Global Positioning System includes a Differential
36 Global Positioning System.

1 27. A survey apparatus according to either one of
2 claims 24 to 26, wherein the signal from the position
3 fixing system is processed to provide data to the
4 processor.

5

6 28. A survey apparatus according to any preceding
7 claim, wherein the survey apparatus is mounted on a
8 mounting device.

9

10 29. A survey apparatus according to claim 28, wherein
11 the mounting device comprises a tripod stand.

12

13 30. A survey apparatus according to any preceding
14 claim, wherein the apparatus can be mounted on an
15 elevating platform, telescopic elevating tube,
16 telescopic arm or robotic arm.

17

18 31. A survey apparatus according to claim 30, wherein
19 the elevating platform, telescopic elevating tube,
20 telescopic arm or robotic arm is capable of 360°
21 rotation.

22

23 32. A survey apparatus according to either claim 29 or
24 claim 30, wherein the elevating platform, telescopic
25 elevating tube, telescopic arm or robotic arm is
26 mounted on a vehicle.

27

28 33. A survey apparatus according to claim 32, wherein
29 the apparatus allows data gathering from within the
30 vehicle to construct a digital terrain model of the
31 terrain surrounding the vehicle.

32

33 34. A method of measuring the range to a target, the
34 method comprising the steps of
35 providing a camera to view a target area;
36 providing a range finder;

1 using the camera to produce an image of the target
2 area;
3 selecting the target within the target area;
4 generating horizontal and vertical angles between
5 a reference point and the target; and
6 moving the range finder and/or camera, if
7 required, through the generated horizontal and vertical
8 angles to measure the range to the target.

9
10 35. A method according to claim 34, wherein the camera
11 comprises a video camera.

12
13 36. A method according to either claim 34 or claim 35,
14 wherein the camera comprises a digital camera.

15
16 37. A method according to any preceding claim, wherein
17 the apparatus includes a display device to allow a user
18 of the apparatus to view a target area using the
19 camera.

20
21 38. A method according to claim 37, wherein the
22 display device comprises a VGA monitor.

23
24 39. A method according to any one of claims 34 to 38,
25 wherein the processor comprises a computer.

26
27 40. A method according to any one of claims 34 to 39,
28 wherein the range finder comprises a laser range
29 finder.

30
31 41. A method according to any one of claims 34 to 40,
32 wherein the range finder is bore-sighted with the
33 camera.

34
35 42. A method according to any one of claims 34 to 41,
36 wherein the image is digitised.

1 43. A method according to claim 42, wherein the image
2 comprises a plurality of pixels.

3

4 44. A method according to claim 43, wherein the
5 reference point comprises a pixel within the target
6 area.

7

8 45. A method according to any one of claims 34 to 43,
9 wherein the reference point comprises a centre point of
10 the target area.

11

12 46. A method according to any one of claims 42 to 45,
13 wherein the target is selected by selecting a pixel
14 within the target.

15

16 47. A method according to claim 46, wherein the target
17 pixel is selected using a mouse pointer.

18

19 48. A method according to any one of claims 34 to 47,
20 wherein the method comprises the further steps of
21 obtaining a focal length of the camera;
22 obtaining a field of view of the camera;
23 calculating the principal distance of the camera;
24 obtaining the horizontal offset and vertical
25 offset between an axis of the camera and an axis of the
26 laser;

27 calculating the horizontal and vertical offsets in
28 terms of pixels;

29 calculating the difference between the horizontal
30 and vertical offsets in terms of pixel and the x and y
31 coordinates of the target pixel; and

32 calculating the horizontal and vertical angles.

33

34 49. A method according to any one of claims 34 to 48,
35 wherein the apparatus includes a pan and tilt unit for
36 panning and tilting of the range finder and/or camera.

1

2 50. A method according to claim 49, wherein the pan
3 and tilt unit comprises a first motor for panning of
4 the range finder and/or camera, and a second motor for
5 tilting of the range finder and/or camera.

6

7 51. A method according to either claim 49 or claim 50,
8 wherein operation of the first and second motors is
9 controlled by the processor.

10

11 52. A method according to any one of claims 49 to 51,
12 wherein the pan and tilt unit includes first and second
13 digital encoders for measuring the angles of pan and
14 tilt.

15

16 53. A method according to claim 52, wherein the
17 outputs of the first and second encoders is fed to the
18 processor.

19

20 54. A method according to claim 53, wherein a feedback
21 loop is provided wherein the motors are operated to pan
22 and tilt the range finder and/or camera through the
23 generated horizontal and vertical angles, and the
24 encoders are used to check the angles to ensure that
25 the range finder and/or camera were panned and tilted
26 through the correct angles.

27

28 55. A method according to any one of claims 48 to 54,
29 the method comprising the further steps of

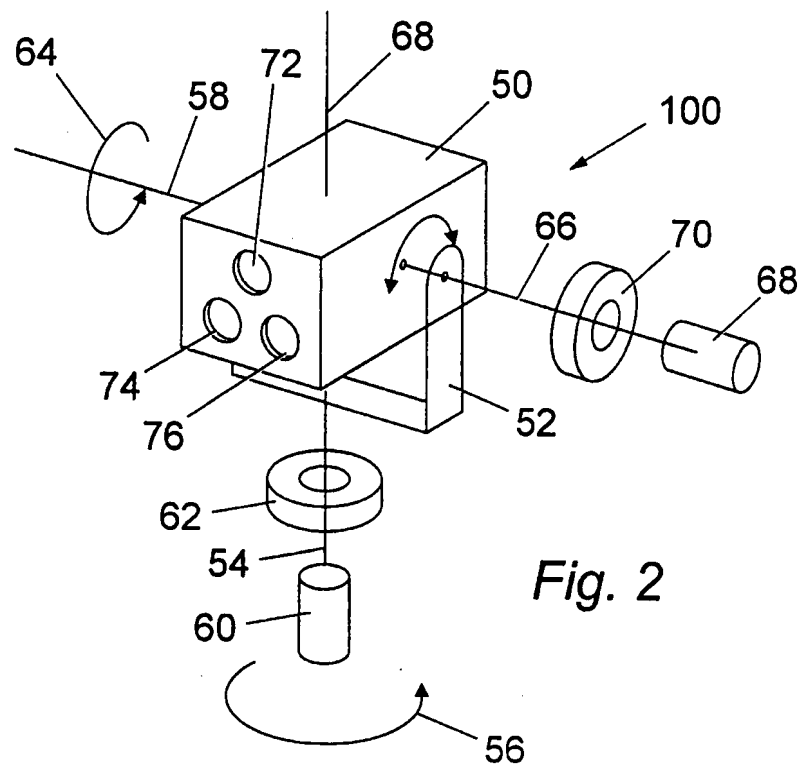
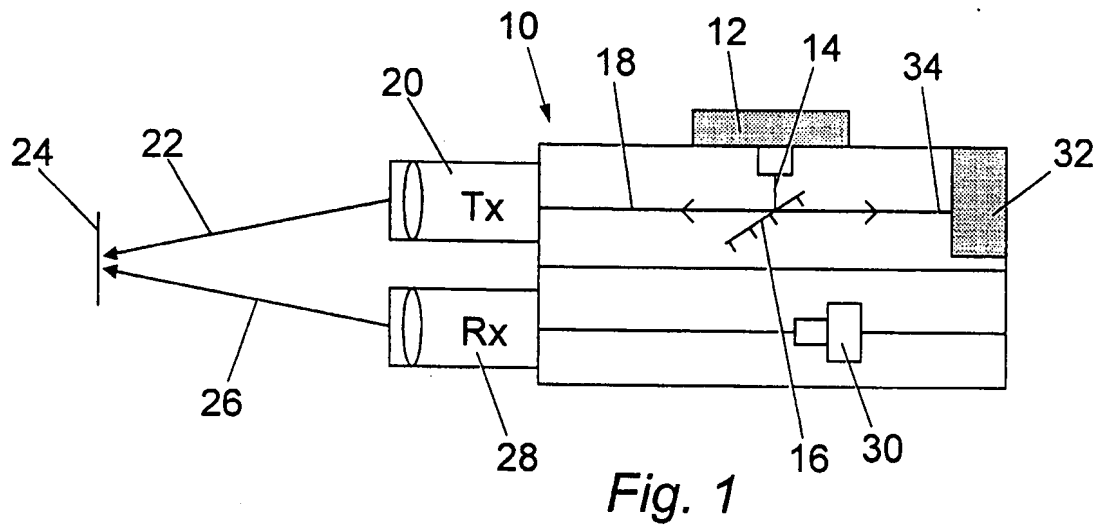
30 instructing the pan and tilt unit to pan and tilt
31 the range finder and/or camera through the vertical and
32 horizontal angles;

33 measuring the horizontal and vertical angles using
34 the encoders;

35 verifying that the angles through which the range
36 finder and/or camera are moved is correct;

1 obtaining horizontal and/or vertical correction
2 angles by subtracting the measured horizontal and
3 vertical angles from the calculated horizontal and
4 vertical angles;
5 adjusting the pan and tilt of the range finder
6 and/or camera if necessary; and
7 firing the range finder to obtain the range to the
8 target.
9

1 / 11



2 / 11

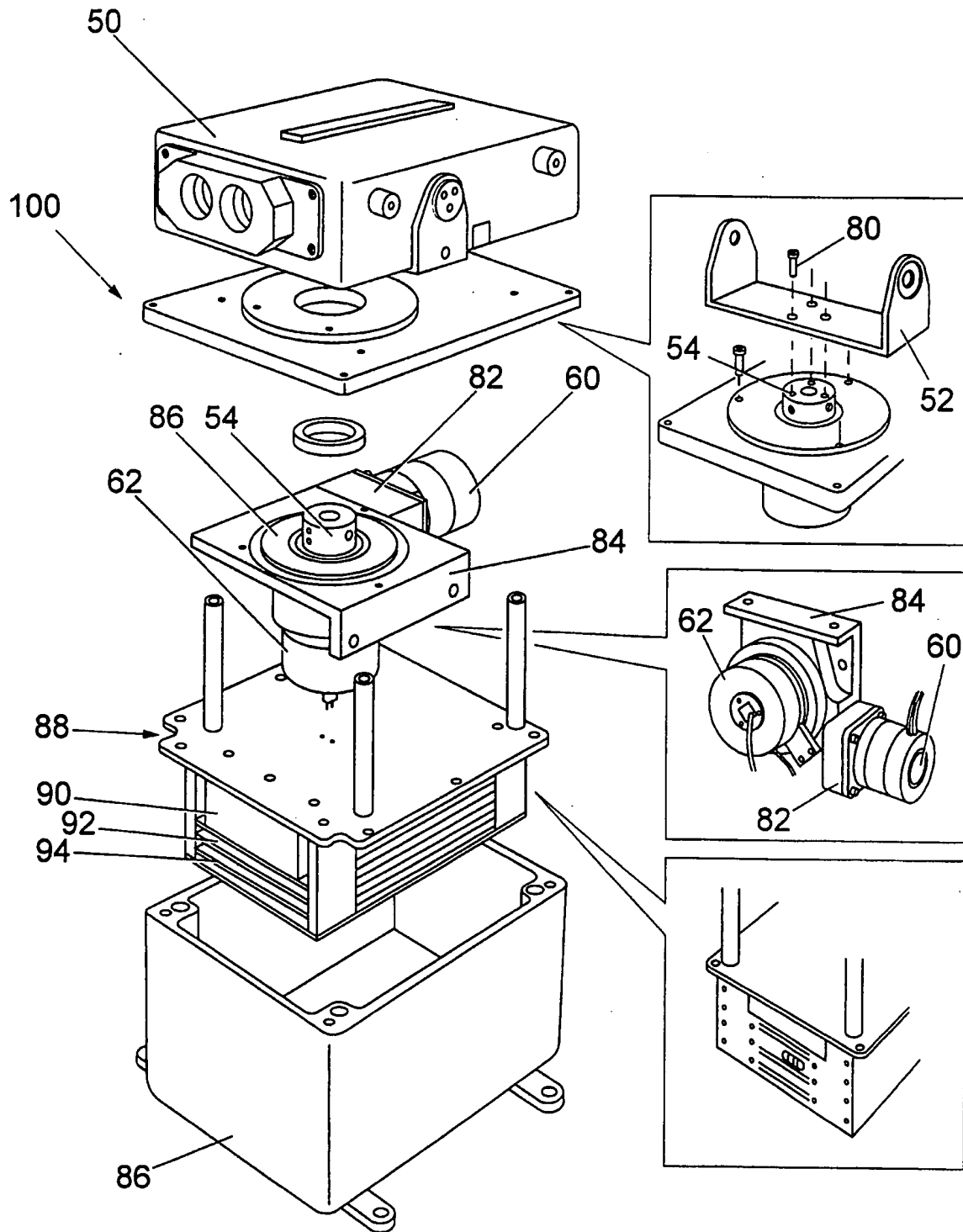


Fig. 3

3 / 11

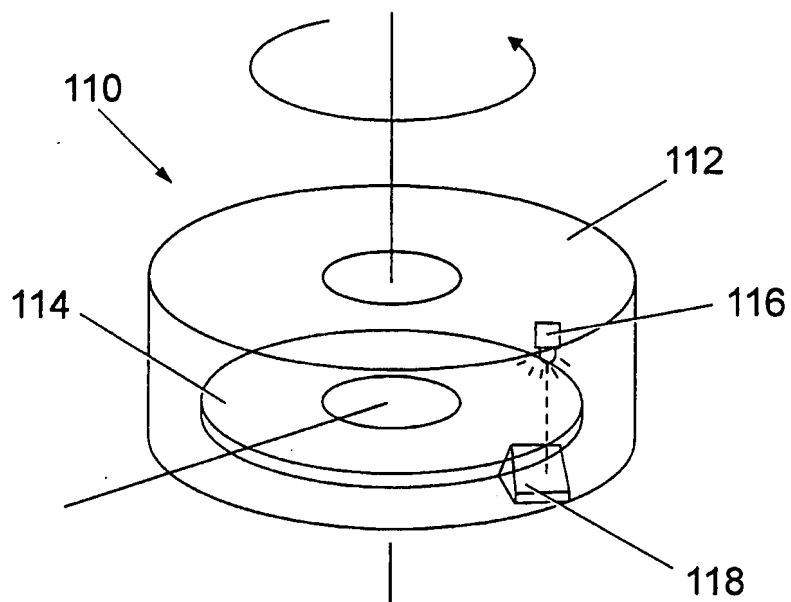


Fig. 4

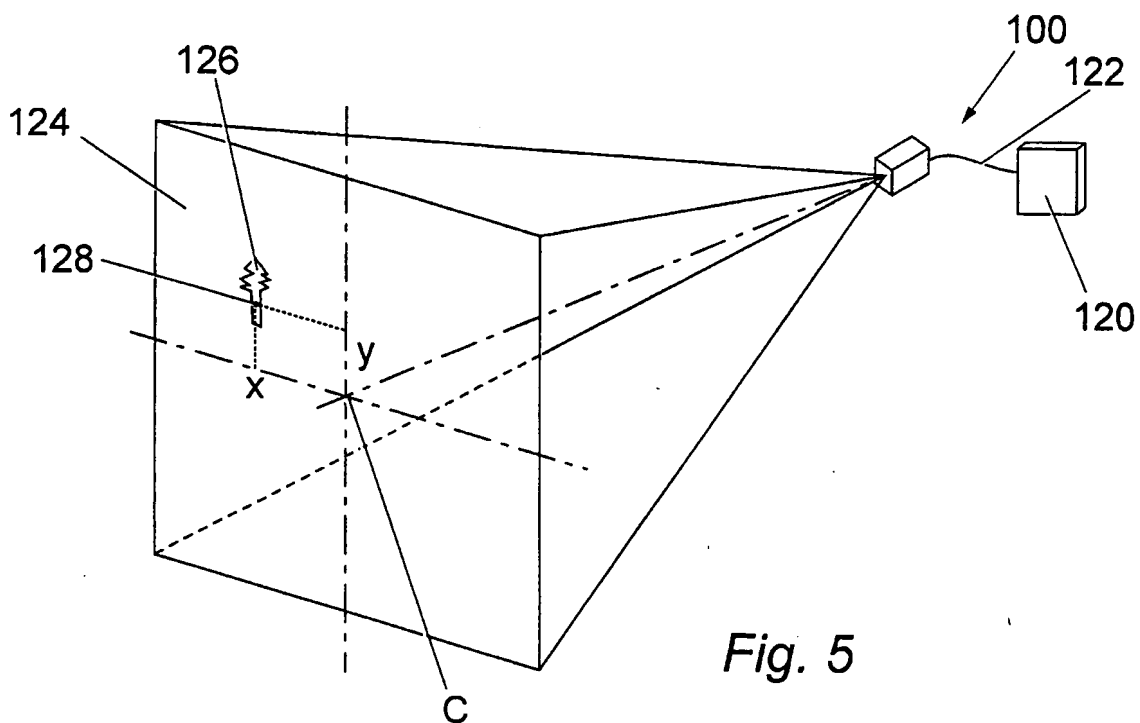
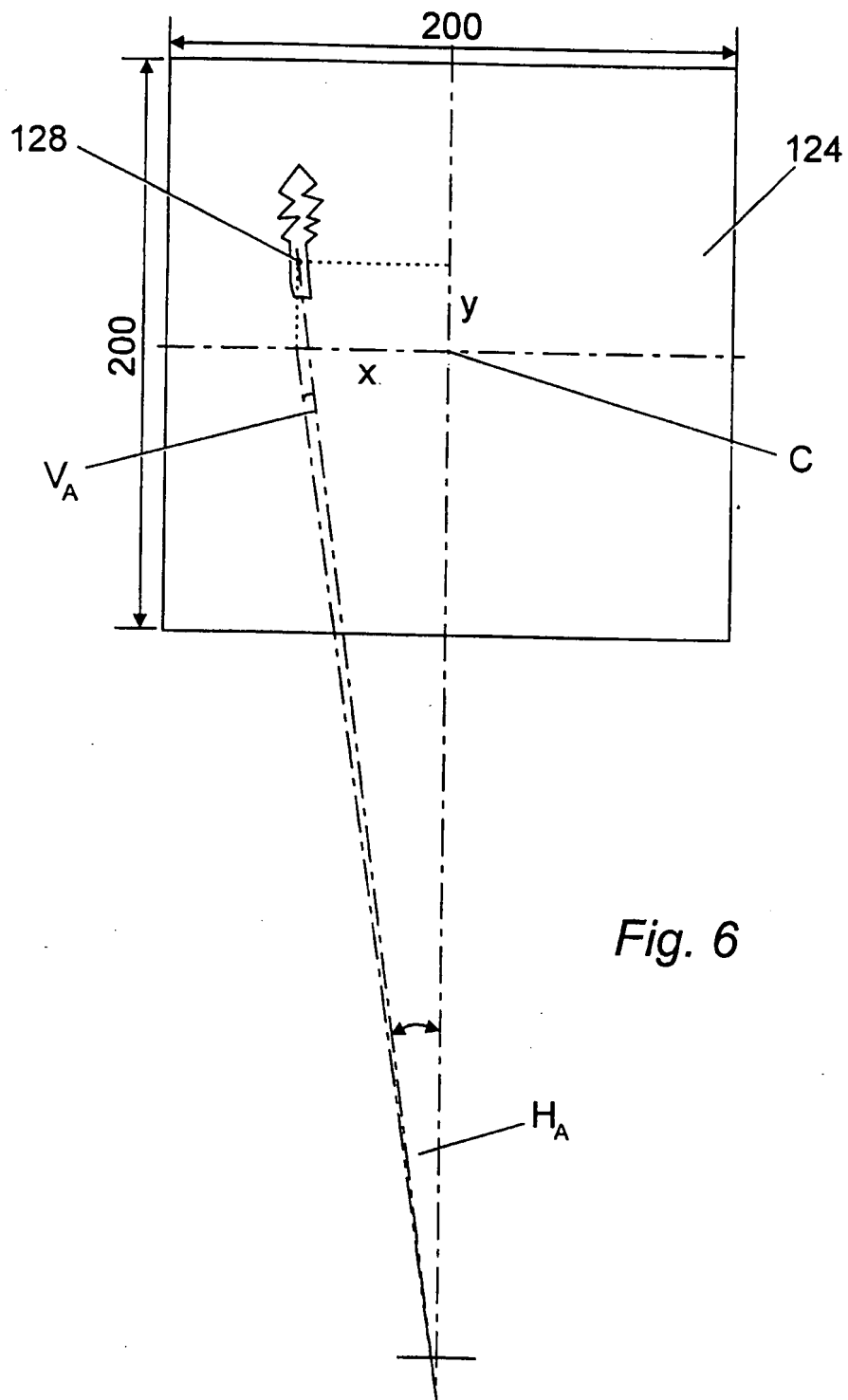
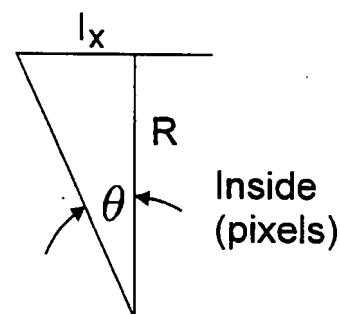
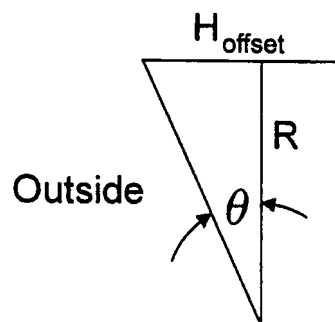
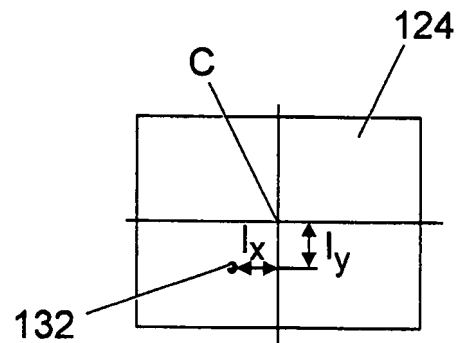
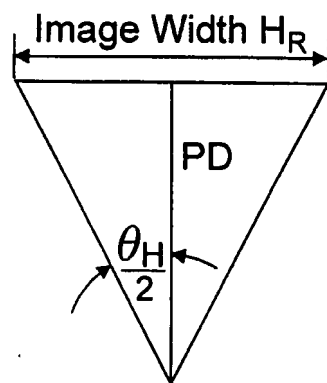
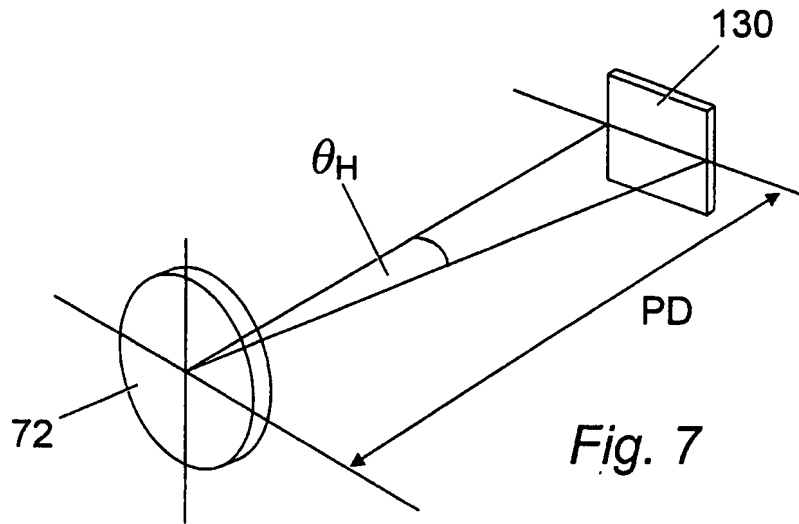


Fig. 5

4 / 11



5 / 11



6 / 11

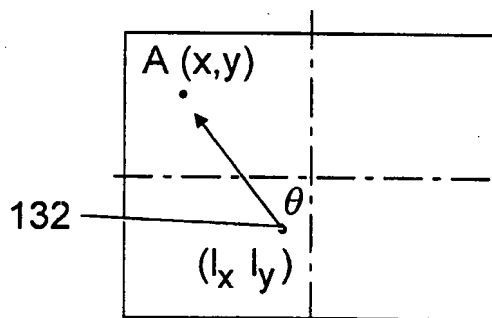


Fig. 12

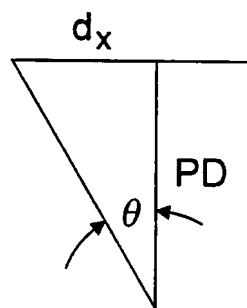
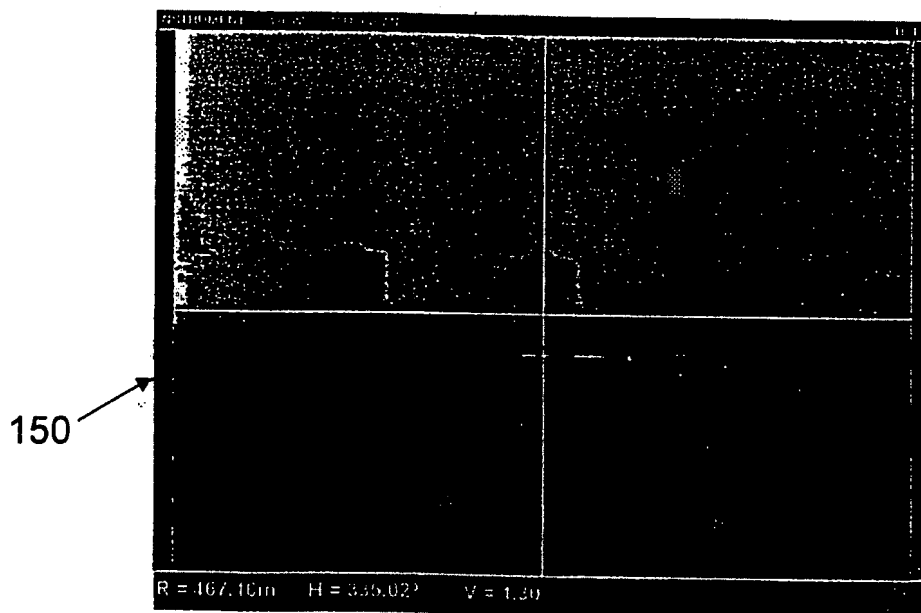


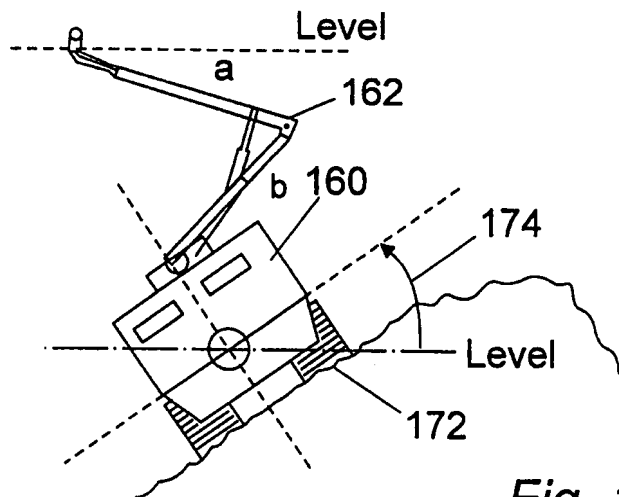
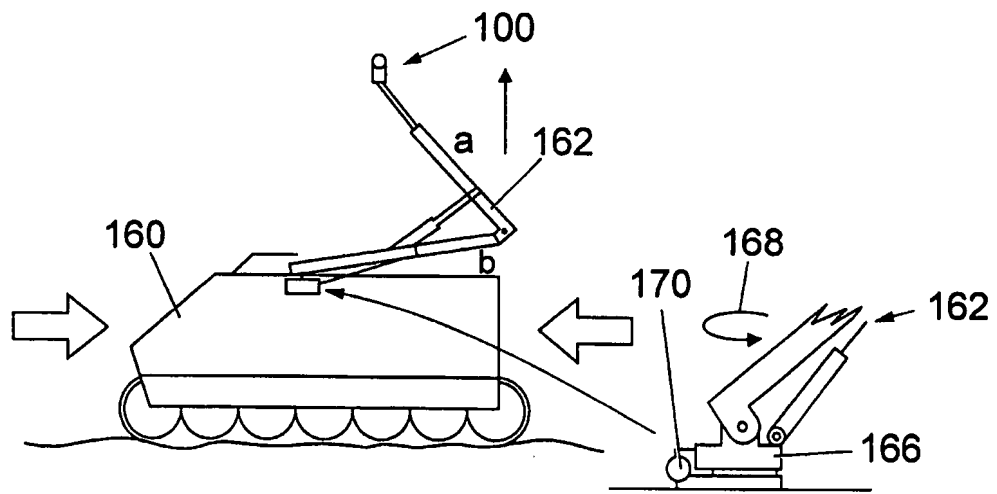
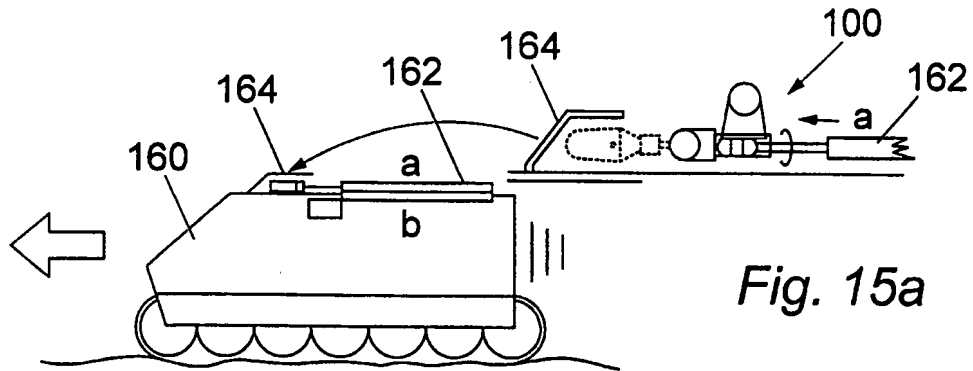
Fig. 13



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Fig. 14

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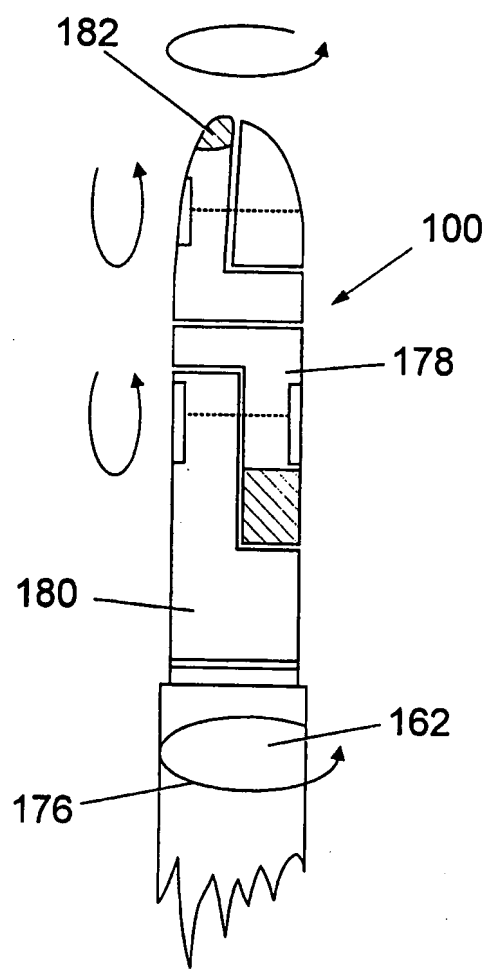


Fig. 16a

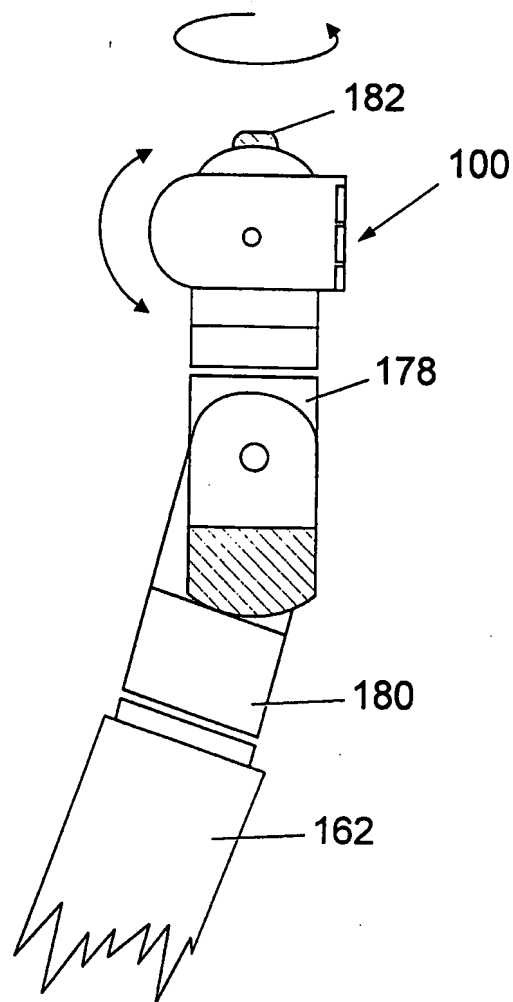


Fig. 16b

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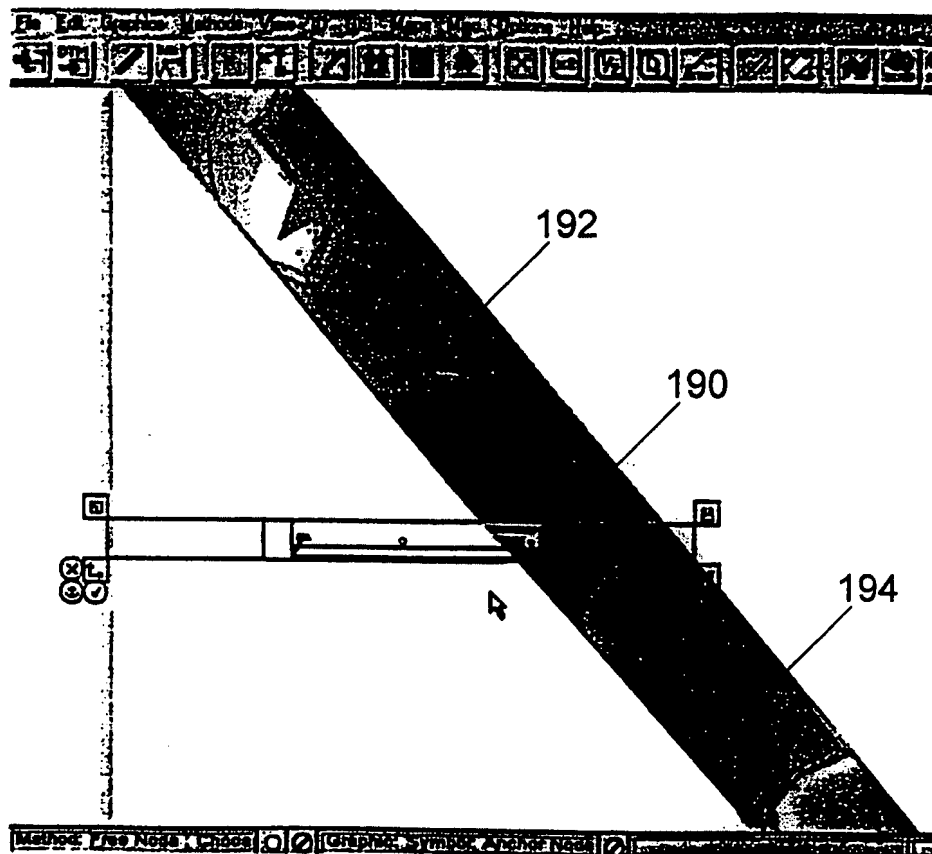


Fig. 17

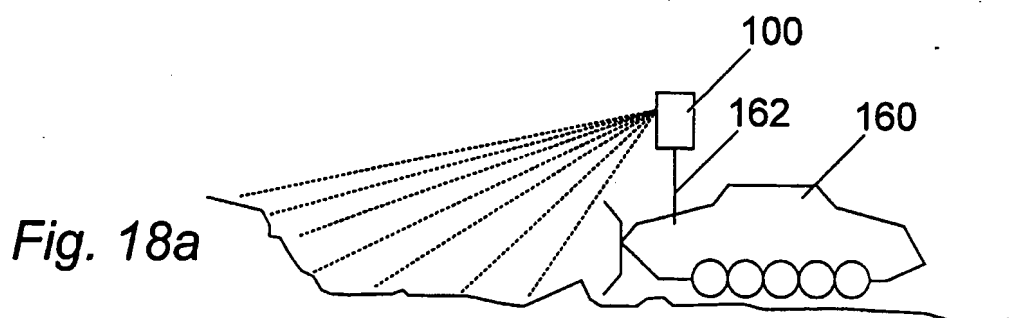


Fig. 18a

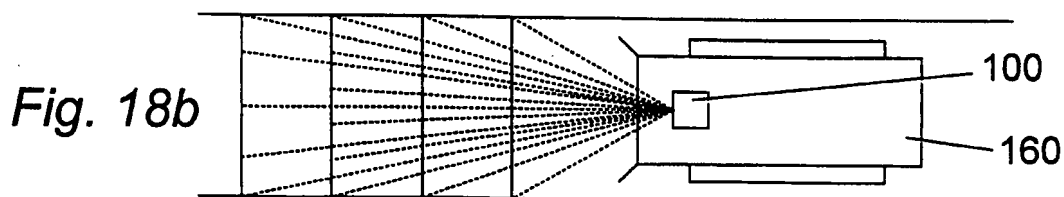
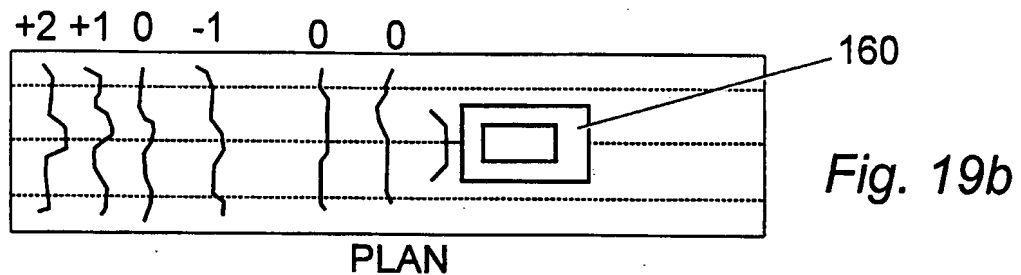
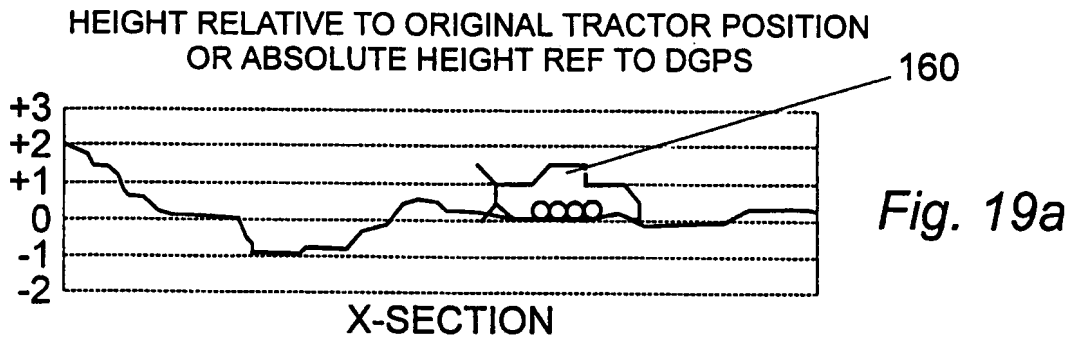
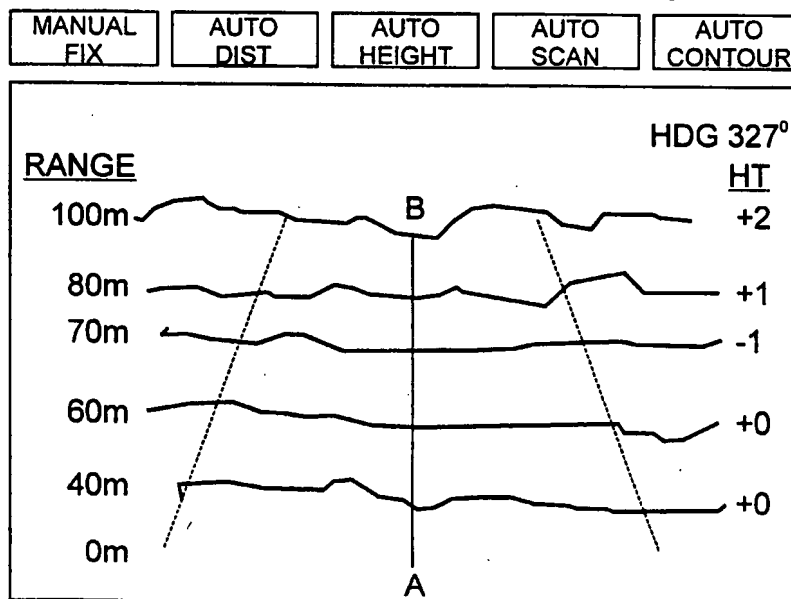


Fig. 18b

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VIDEO VIEW
GRAPHICS OVERLAY ON VIDEO CORRECTED FOR
PROJECTED TANK / CAMERA-HEADING



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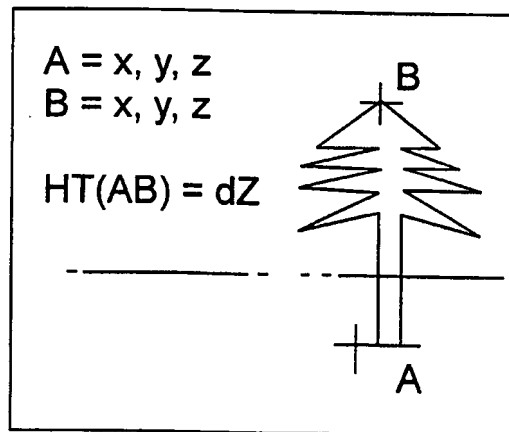


Fig. 21

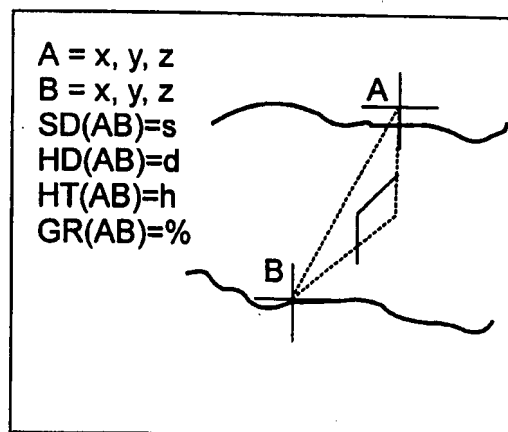


Fig. 22

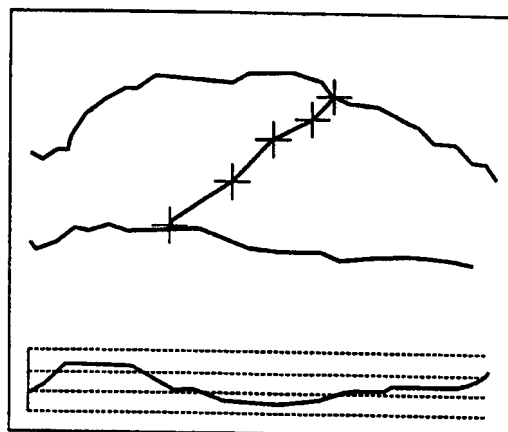


Fig. 23

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/01361

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01C15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 481 278 A (PIETZSCH IBP GMBH) 22 April 1992 (1992-04-22)	1, 4-7, 9-14, 34, 37-40, 49-54
Y	column 4, line 17 - line 23	21, 23-25, 27, 28, 30, 32, 33
Y	column 5, line 28 - column 7, line 11; figures --- US 5 077 557 A (INGENSAND HILMAR) 31 December 1991 (1991-12-31) column 2, line 4 - line 17; figures --- -/--	21, 23-25, 27, 28



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

19 August 1999

Date of mailing of the international search report

26/08/1999

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/01361

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 379 045 A (GILBERT CHARLES ET AL) 3 January 1995 (1995-01-03) column 9, line 51 - column 10, line 4 column 13, line 1 - line 6; figures 1,2 ---	30,32,33
X	EP 0 661 519 A (TOPCON CORP) 5 July 1995 (1995-07-05) the whole document -----	1,3-6, 8-13, 34-39, 41,45, 49-53

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Information on patent family members

International Application No

PCT/GB 99/01361

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